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A Model to Evaluate Elk Habitat in Western Oregon

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March 1986

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A Model to Evaluate Elk Habitat in Western Oregon

by

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Foreword

This habitat evaluation model for western Oregon is part of a continuing, multi-agency effort to understand the relationships between wildlife and habitat, and apply that knowledge to resource management planning. Its specific purpose is to provide an understandable, uniformly applicable technique to assess elk habitat. Future improvements and further applications of the model are expected to be part of this effort, in the same way that this model grew from earlier efforts. Proper management of elk habitat, and all the public lands, requires constant improvement in the quantity and quality of information available to managers.

We commend those who have contributed to this model, and fully support its use in forest management and planning. It is our intention that the model be applied and tested by wildlife biologists and forest managers to evaluate elk habitat on National Forest, Bureau of Land Management, and State lands in western Oregon. We are confident that such efforts will improve communication, strengthen our informational base, and clarify options for integrating the management of elk habitat with other forest uses.

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Introduction

Forest managers need standard methods to measure the effects of land use proposals on Roosevelt elk (Cervus elaphus roosevelti) habitat. One such method was developed for Rocky Mountain elk (C. e. nelsoni) in the Blue Mountains of northeastern Oregon (Thomas et al. 1979: 107-127). This technique has been widely applied and served as a guide for the development of similar models elsewhere. Relationships of elk use in response to sizing and spacing of forest stands and openings, habitat quality, and road density were presented, and provided a basis for development of cover-forage area ratios and road density as a standard evaluation method.

Since that time, cover-forage ratios have been used with varying reliability to evaluate elk habitat in many areas of the intermountain west. Reliability of the method depends upon adherence to the inherent assumptions that areas of forage and cover are within optimal sizing and spacing, that limitations on the amount of thermal cover are met, and that quality of forage is not limiting.

During the development of habitat relationships for elk in western Oregon and Washington (Witmer et al. 1985), it was found that many areas did not meet these assumptions, and that more specific measurements of sizing and spacing of forage and cover areas, habitat quality, and effects of human disturbance were needed. As a result, this paper presents a model to evaluate elk habitat based on the interactions of four variables: (1) sizing and spacing of forage and cover; (2) road density; (3) cover quality; and (4) forage quality. Model structure closely follows that found in habitat suitability index models (U. S. Fish and Wildlife Service 1981). The following assumptions were made as prerequisites to its development:

1. Relationships of habitat use and definitions of forage and cover types presented by Witmer et al. (1985) provide a framework for evaluation.
2. Analysis can be done primarily by computer, with little or no manual computation required. Computer programs are available that use this model to evaluate habitat from maps generated from Landsat Digital Imagery (Eby and Bright 1986). Use of automated systems, however, require the user to verify the digitized maps in the field.
3. Areas of large, intermediate, or small size can be assessed with equal reliability. Evaluation of potential changes through time, however, will be valid only if the boundaries of the original area remain the same during subsequent assessments.
4. All regions of western Oregon can be evaluated with equal reliability, including both summer and winter range.
5. Evaluation of habitat variables can be expressed in terms of habitat effectiveness. Habitat effectiveness is defined as the proportion of achievement relative to an optimum condition. Conditions range from optimum use (1.0) to minimum use (0.05).
6. All four habitat variables – sizing and spacing, road density, cover quality, and forage quality – play important roles in affecting elk use of habitat, and must be included in any assessment. Other habitat variables could be added to the model during future modifications.
7. Interactions between habitat variables can be integrated to obtain one index of habitat effectiveness.
8. Habitat effectiveness reflects the potential for change in elk use relative to past or future levels of effectiveness for the same area. Habitat effectiveness does **not** equate to population densities of elk, nor does it account for the effects of local hunting regulations. However, changes in habitat effectiveness reflect potential trends in population densities compared to past levels of effectiveness for the same area.
9. Comparisons of habitat effectiveness between areas will be accurate only if site capability as affected by slope, aspect, soil, and climate is similar between the areas. Habitat effectiveness cannot be compared between areas if significant differences in site capability exist.
10. Additional, field-intensive methods of evaluation can be used to supplement and improve the reliability of the model.
11. The model can be validated through research and field application. Validation testing can function as a catalyst for future modifications and improvements.

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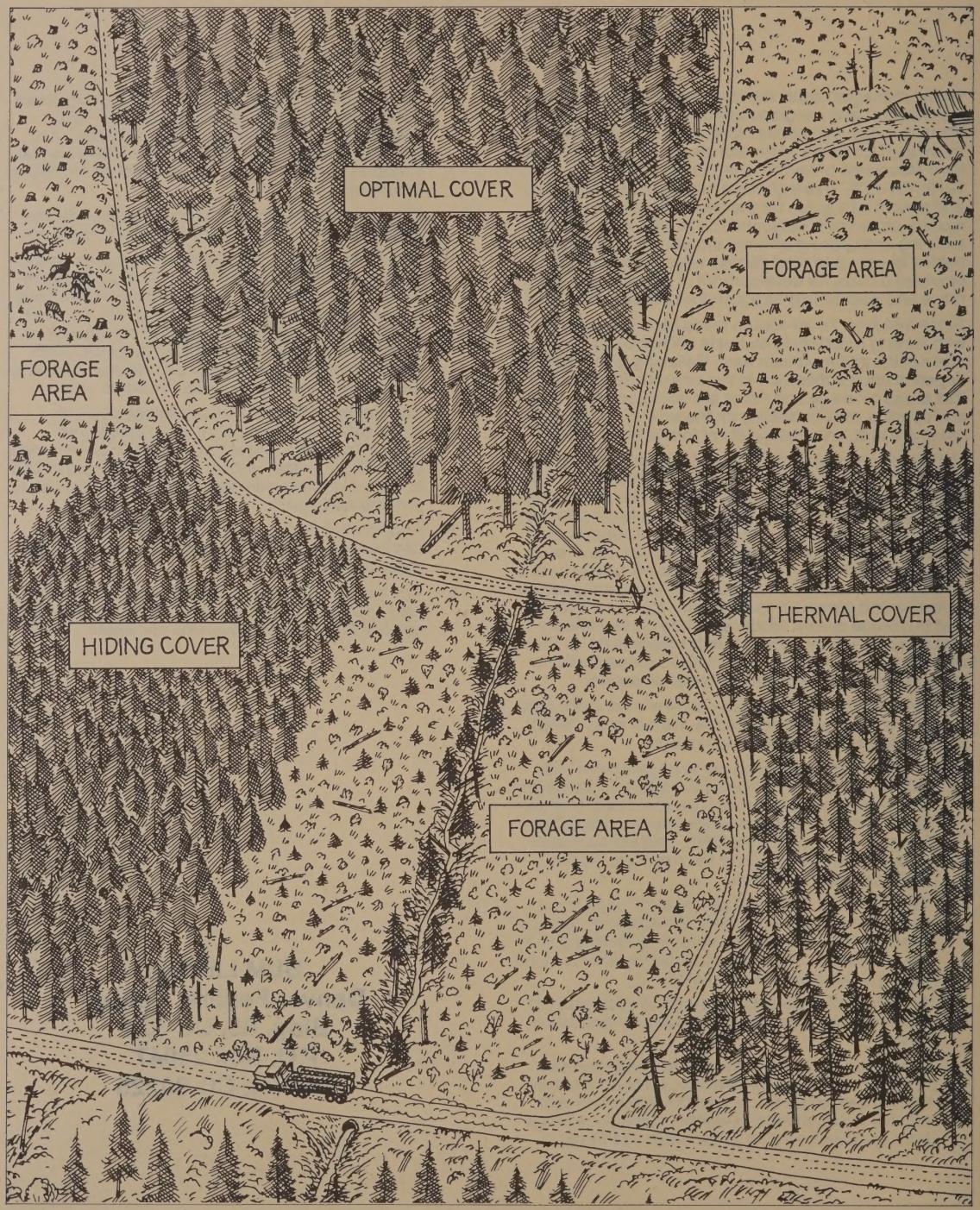

Figure 1. Landscape view of a managed forest in western Oregon.

Habitat Variables

Managed forests in western Oregon are composed of a landscape of successional stages interconnected by a network of roads (Figure 1). The interspersion of forage and cover areas in time and space, their relative quality, and the effects of human disturbance from roads open to motorized vehicles are the major factors affecting elk use (Witmer et al. 1985), as shown in the following sections.

Variable 1: Sizing and Spacing of Forage and Cover Areas

The way that forage and cover are interspersed affects the time and energy required by elk to fully use both habitat components. Maximum intake and least expenditure of energy by elk occurs when forage and cover are of appropriate size and close proximity; this results in maximum energy available for maintenance, growth, and reproduction. As forage and cover areas become larger than optimum, less of the total area is used by elk (Figure 2).

Figure 2. Forage and cover areas in close proximity to each other (Figure 2A) will receive higher use by elk than areas farther apart (Figure 2B).

Figure 2A.

Figure 2B.

This concept is illustrated by the forage and cover area use curve developed by Witmer et al. (1985:237-240), shown in Figure 3. This curve is based on data from studies in western Oregon (Harper and Swanson 1970, Witmer 1981), western Washington (Hanley 1983) and Vancouver Island (Willms 1971) that show decreased use by deer or elk as the distance away from the cover-forage edge increases. Although these studies vary in terms of how quickly the decline in use occurs with increasing distance away from edge, their net effect is reflected in Figure 3.

Based on this effect, the majority of elk use of forage areas occurs within 100 yards of the edge with cover. Similarly, most elk use of cover occurs within 300 yards of the edge with forage (Figure 4). There is one exception to this rule, however. When cover areas are not large enough to exceed 100 yards from the edge with forage (or 200 yards in width), they receive less than optimum use (Figure 5).

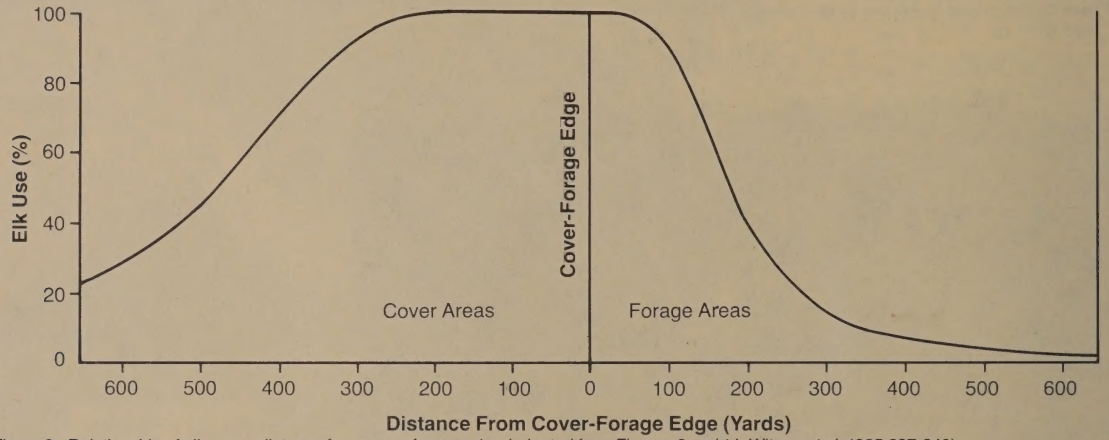

Figure 3. Relationship of elk use to distance from cover-forage edge (adapted from Figures 8 and 14, Witmer et al. 1985:237-240).

Figure 4. The cover-forage edge is the reference point for evaluation of elk use in relation to sizing and spacing of habitats.

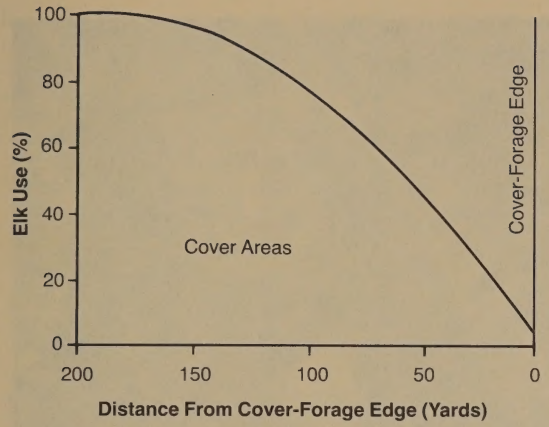

Figure 5. Relationship of elk use of cover areas to distance from cover-forage edge when cover areas are not large enough to exceed 100 yards from the edge (adapted from Figure 14, Witmer et al. 1985:240).

The relationship between habitat effectiveness and elk use at various distances away from edge is shown in Table 1. This relationship was developed by splitting Figures 3 and 5 into 100-yard distance bands away from the cover-forage edge. Each distance band was assigned a rating of habitat effectiveness that ranged from 1.0 (full use) to .05 (least use), based on the mid-point value within each interval; these ratings form the basis for evaluation of sizing and spacing of forage and cover areas, as shown later.

Table 1. Ratings of habitat effectiveness by 100-yard distance bands away from the cover-forage edge, based on elk use (Figures 3 and 5).

	Distance from Cover-Forage Edge (Yards)	Percent Use from Figure 3	Rating of Habitat Effectiveness
	>400	5	0.05
	301–400	10	0.10
Forage Area	201–300	25	0.25
	101–200	70	0.70
Edge	0–100	100	1.0
	0–300[1]	100	1.0
Cover Area	301–400	80	0.80
	401–500	60	0.60
	501–600	40	0.40
	>600	20	0.20

[1] *Cover areas not large enough to exceed 100 yards from edge (or 200 yards in width)*

	Distance from Cover-Forage Edge (Yards)	Percent Use from Figure 5	Rating of Habitat Effectiveness
	0–100	50	0.50

Variable 2: Density of Roads Open to Motorized Vehicles

Elk use of habitat is dramatically and adversely affected by roads (Figures 6 and 7) open to vehicular traffic (Perry and Overly 1977, Thomas et al. 1979, Lyon 1983, Witmer and deCalesta 1985).

Figure 6. Human disturbance allowed by motor vehicle access reduces elk use of habitat adjacent to roads.

Figure 7. The density of roads increases with the need to access areas for timber harvest and to apply silvicultural treatments.

The relationship between road density and habitat effectiveness in western Oregon (Witmer and deCalesta 1985) is similar to a road-habitat model constructed by Thomas et al. (1979) and refined and validated by Lyon (1983). The refined model (Lyon 1983) is used here as the criterion to determine the influence of roads open to vehicular traffic on habitat effectiveness (Figure 8).

This relationship applies only to areas where elk are hunted. In specially protected areas such as Jewell Meadows and Dean Creek in western Oregon, unhunted herds of elk apparently do not perceive vehicular traffic as a threat or source of disturbance. In such areas, habitat effectiveness as influenced by roads (Figure 8) would remain at an optimum level (1.0) when conducting an evaluation.

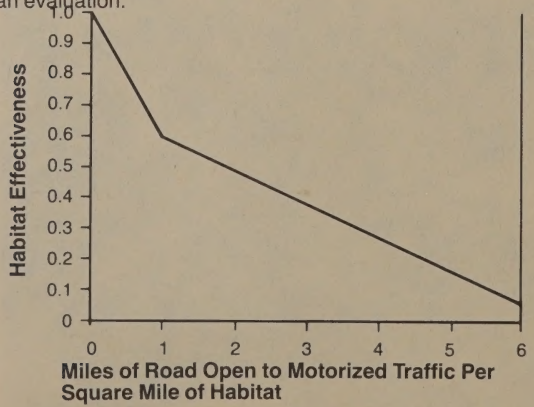

Figure 8. Relationship of density of roads open to motorized vehicles to habitat effectiveness (Lyon 1983).

Any road open to motorized vehicles must be included in the calculation of road density when using Figure 8. To date, no studies have measured the effect of the number of vehicular trips per unit of time on elk use; therefore, we assume that road closures for elk will only be successful when vehicular entry is completely restricted or extremely limited, as indicated by the current research (Perry and Overly 1977, Thomas et al. 1979, Lyon 1983, Witmer and deCalesta 1985). It should be recognized that **any** traffic increases the likelihood that elk will avoid adjacent habitat. There is no information that indicates that low traffic levels are any less damaging to elk than high levels.

It follows that road closures for elk must be designed to minimize the frequency of motorized traffic entering a closed area. This will require setting objectives that limit the number of vehicular trips entering a closed area per unit of time, and then monitoring the actual frequency of vehicular entries. This includes vehicles used by land managers.

If the frequency of vehicular entries exeeds the level chosen as an objective, the road is considered open to motorized traffic for purposes of conducting this evaluation. Again, remember that no information exists to indicate that low levels of traffic are any less harmful to elk than high levels. Until more information is available, we assume the success of road closures for elk will depend entirely on enforcing strict limits on the frequency of motorized traffic.

Variable 3: Cover Quality

Three types of cover are used by elk in western Oregon: optimal, thermal, and hiding cover (Witmer et al. 1985). Optimal cover is defined as a forest stand with: 1) four layers consisting of overstory canopy, sub-canopy, shrub layer, and herbaceous strata; and 2) an overstory canopy

which can intercept and hold a substantial amount of snow, yet has dispersed, small (less than 1/8 acre) openings. These criteria are generally achieved when the dominant trees average 21 inches diameter breast height (d.b.h.) or greater, have 70 percent or greater crown closure, and are in the large sawtimber or old-growth stand condition (Witmer et al. 1985).

Thermal cover is a forest stand at least 40 feet in height with tree canopy cover of at least 70 percent; this is achieved in many closed sapling-pole stands and by all older stands unless the canopy cover is reduced below 70 percent (Witmer et al. 1985).

In contrast to optimal and thermal cover, hiding cover is not defined in terms of stand structure. Any vegetation capable of hiding 90 percent of a standing adult deer or elk at 200 feet or less qualifies as hiding cover (Thomas et al. 1979), provided such areas do not meet the structural definitions of thermal cover, optimal cover, or forage areas. In western Oregon, hiding cover includes some shrub stands and all forested stand conditions with adequate tree stem density or shrub layer to hide animals (Witmer et al. 1985).

The three cover types differ from each other in the benefits they provide to elk. Optimal cover is thought to be used by elk to: 1) hide from predators and avoid disturbances, including man; 2) modify extremes in climate and thus regulate body temperature; and 3) provide forage during periods when food in other areas is unavailable due to weather or human disturbance (Figures 9 and 10).

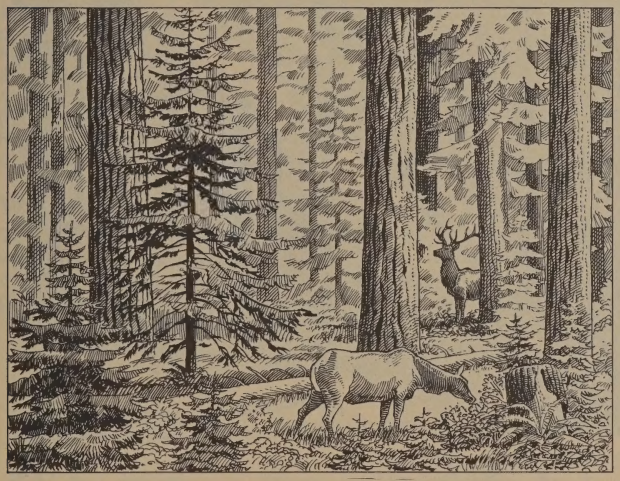

Figure 9. Optimal cover modifies ambient climate, allows escapement from human harassment, and provides forage.

Figure 10. During intense or prolonged snowstorms, elk may depend on optimal cover to intercept snowfall and provide forage in the form of litterfall lichens and mosses and understory vegetation.

In southwestern Oregon, differences in the amount of optimal cover (in the form of old-growth) accounted for a majority of the variation in elk densities across 18 drainages (Smithey et al. 1985). Preference for optimal cover also was documented in other studies in southwestern Oregon (Witmer 1981) and western Washington (Zahn 1985). Although data are limited, we assume that similar relationships exist in other areas of the Coast, Cascade, Siskiyou and Klamath Mountains of western Oregon.

Thermal and hiding cover (Figures 11 and 12) differ from optimal cover in the uses that elk make of them (Witmer et al. 1985). Like optimal cover, some older stands of thermal cover may contain large overstory trees with branching sufficient to intercept and hold moderate snowfall, block and reflect solar radiation, and provide litterfall forage in the form of lichens and mosses. Some openings in the overstory may also be present to allow for growth of understory forage available to elk during periods of heat or cold stress. These functions, however, are not well-developed in contrast to optimal cover, particularly in younger thermal cover and hiding cover where these functions may be absent.

Younger thermal cover modifies extremes in temperature, windspeed, and solar radiation, and provides security from disturbances and predators. Hiding cover provides security and escapement from harassment and predators,

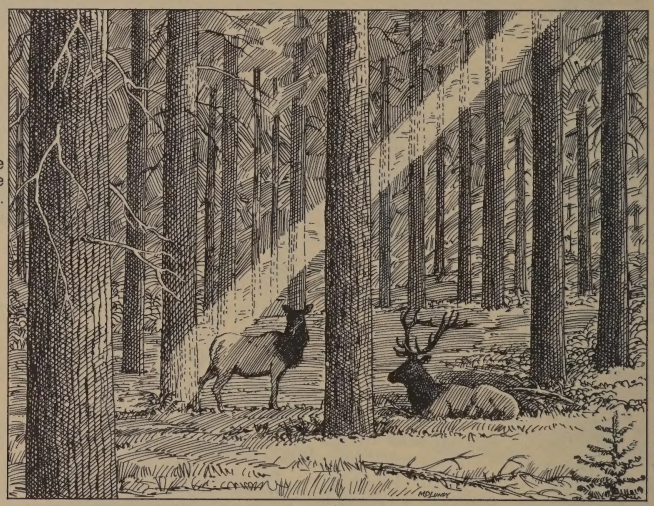

Figure 11. Thermal cover modifies extremes in climate and provides security from disturbances but may not provide forage needed during periods of heat or cold stress.

Figure 12. Like optimal and thermal cover, hiding cover allows elk to escape human disturbances, but other functions provided by older cover types may be absent.

but performs few other functions provided by older cover types (Witmer et al. 1985).

A conceptual relationship between habitat effectiveness and the cover types is shown in Figure 13. This relationship is based on the concepts of use of westside cover types, discussed here and inferred by Witmer et al. (1985) from several westside studies (Janz 1980, Rochelle 1980, Witmer 1981, Zahn 1985). In general, the increase in functions provided by cover follows succession and age of a stand, although silvicultural treatments applied can regress or possibly accelerate the process (Witmer et al. 1985).

Based on Figure 13 and the process described below, we assigned the following weights of habitat effectiveness to each cover type: optimal cover – 1.0; thermal cover – 0.5; and hiding cover – 0.1. These ratings were developed from estimates of use provided by the authors of Witmer et al. (1985). Each of the 10 biologists was asked to rate potential elk use from 0-100% for each of the three cover types. The mean of the 10 values for each cover type was then calculated to derive estimates of habitat effectiveness. This is a modification of the "Delphi Technique" (Helmer-Hirschberg and Rescher 1960, Gordon and Helmer-Hirschberg 1964). Use of these estimates to evaluate cover quality is shown later.

Variable 4: Forage Quality

The quality of food available to ruminants is affected by a wide variety of biochemical and nutritional characteristics of plants and divergent conditions that control plant phenology and occurrence. Numerous definitions of forage quality have been proposed in an attempt to describe this array of characteristics and conditions. Dietz (1970) and Nelson and Leege (1982:323-367) discuss this subject thoroughly, and in doing so address nearly all parameters that affect forage quality.

Our evaluation of forage quality for elk habitat in western Oregon is confined to a much narrower scope that relates directly to specific management practices. For that reason it is likely our system may not address the complete range of parameters that contribute to forage quality on a broader scale. The following assumptions form the basis for our evaluation:

(1) Evaluation of forage quality is confined to forage areas. Although some cover areas, particularly optimal cover, provide forage of high quality, this contribution was considered previously during the evaluation of cover quality. The value of forage within cover areas considered the thermal benefits provided by the environment around the forage. In this section, we evaluate the quality of food within areas of open canopies (forage areas) where modification of ambient climate is minimal.

Forage areas in western Oregon are defined by Witmer et al. (1985) as vegetated areas with less than 60 percent combined canopy closure of trees and tall shrubs (Figure 14). Only trees and shrubs over seven feet in height are considered part of the canopy when using this definition. Forage areas include the grass-forb, shrub, and open-sapling pole stand conditions and may include some older stands that have been thinned. In a managed forest the primary forage areas are those that have had all or most of the forest canopy removed by clearcutting or shelterwood cutting (Witmer et al. 1985).

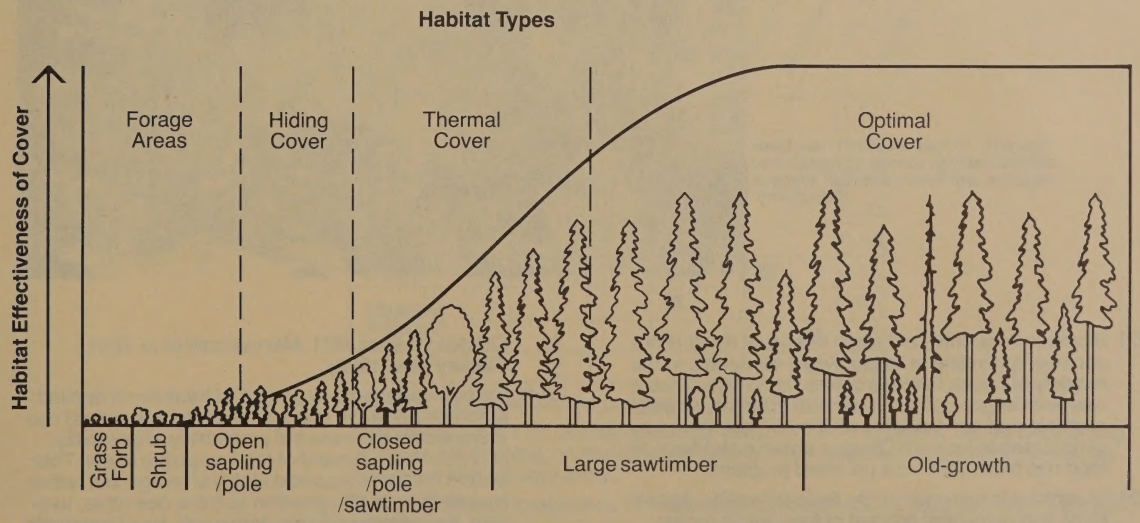

Figure 13. Conceptual relationship between habitat effectiveness of cover areas and development of cover types and stand conditions through time.

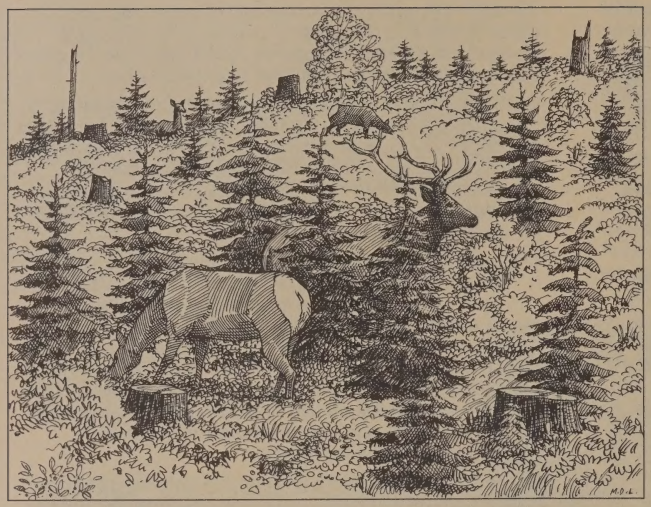

Figure 14. Due to their open canopy, forage areas are usually dominated by grasses, forbs, shrubs, and small trees.

Figure 15. Forage areas that have been clearcut, burned, seeded with grasses or legumes, and fertilized contain forage of high quality.

(2) Biomass or quantity of forage **in and of itself** is not considered limiting or restrictive to elk needs. In the majority of cases, habitats defined as forage areas in western Oregon contain moderate to large quantities of plants that are available as food for elk. We know of no cases in western Oregon where a shortage of food has been cited as a potential problem.

(3) In contrast to forage quantity, the palatability, digestibility, and nutritional content of food within forage areas varies widely. These variables are key to our evaluation of forage quality and are considered potential limiting factors to elk productivity in western Oregon (Trainer 1971, Mereszczak et al. 1981, Starkey et al. 1982).

(4) Certain treatments or groups of treatments applied to forage areas (or used to create forage areas) can dramatically increase the palatability, digestibility, and nutritional content of food available to elk. This occurs not by increased quantity of forage, but rather by a **shift** in its composition to more desirable, useable, and beneficial forms. In this way, land treatments control much of the variation in the quality of food occurring within forage areas.

(5) Palatability, digestibility, and nutritional content of forage reach optimum values in forage areas that have been clearcut, burned during site preparation, seeded with grasses or legumes after burning, and fertilized (Figure 15) during or after seeding (Witmer et al. 1985). As less of these treatments are used, the quality of forage declines.

(6) The beneficial effects of clearcutting, burning, and seeding will last throughout the life of the forage area (until it grows into cover). Fertilization, however, must occur at least every three years to maintain its beneficial effect. Burning and seeding must occur within three years after clearcutting to count as beneficial treatments.

(7) In permanent forage areas such as meadows and pastures, optimum quality of forage occurs following fertilization, or when other beneficial practices such as mowing or haying are combined with or substituted for fertilization. Fertilization or other beneficial practices such as mowing or haying must occur at least every three years to maintain their beneficial effect.

(8) Natural openings consisting of rock outcrops or talus slopes cannot support forage of high quality, and cannot be enhanced due to a dearth or absence of soil. Without adequate soil, plant nutrients are not available to forage species that are needed to maintain their palatability, digestibility, and nutritional benefits for elk.

With these assumptions as the basis for evaluation, we grouped those land treatments having positive effects on forage quality into nine categories, and assigned each category a potential level of habitat effectiveness (Table 2) using the Delphi Technique (Helmer-Hirschberg and Resher 1960, Gordon and Helmer-Hirschberg 1964). These estimates are used to evaluate forage quality as shown later.

One note regarding Table 2 is in order here. We recognize that beneficial treatments applied to pastures or meadows may yield forage of higher quality than non-pasture or non-meadow forage areas treated similarly. This is due primarily to higher site index associated with most pastures and meadows, and in turn, with the wider variety of beneficial treatments that potentially can be applied. For that reason, pastures and meadows should receive highest priority for any forage enhancement projects. Biologists must assess these projects on a case-by-case basis, using site-specific methods that depict the relative benefits in comparison to non-pasture or non-meadow forage areas at the field level.

Table 2. Relationship between habitat effectiveness and treatments used to create forage areas or treatments applied to existing forage areas.

Land Type Before Treatment Application	Treatment Category	Treatments[1]							
		Clearcutting	Burning	Seeding	Fertilization	Commercial Thinning	Shelterwood Cutting	No Treatments	Rating of Effectiveness
Cover[2]	1	■	■	■	■				1.0
	2	■	■	■					0.75
	3	■	■						0.50
	4	■							0.25
	5					■			0.10
	6						■		0.10
Meadow/ Pasture[3]	7				■				1.0
	8							■	0.75
Talus[4]	9							■	0.05

[1]Must be applied within the constraints prescribed in text.

[2]Any forest stand with overstory canopy closure of 60% or higher before clearcutting, commercial thinning, or shelterwood cutting. After treatment application, areas are assumed to be forage areas.

[3]Any **permanent** forage area not classified as cover or talus areas before treatment application.

[4]Any **permanent** forage area dominated by rock outcrops or talus with minimal soil present.

Calculation of Habitat Effectiveness

Relationships Between Habitat Variables

A number of potential relationships can exist between habitat variables in a multivariate evaluation model (U. S. Fish and Wildlife Service 1981). To obtain one index of habitat effectiveness, all variables must be integrated in such a way that best explains the species response to a wide range of habitat conditions. The diverse array of habitat conditions is expressed by the many possible combinations of high, low, and intermediate scores that can be generated from the habitat variables. The manual on habitat suitability index models developed by the U. S. Fish and Wildlife Service (1981) provides a thorough review of this topic.

For elk in western Oregon, the interactions between sizing and spacing, road density, and cover and forage quality appear to be compensatory; that is, variables with low scores tend to be compensated by those with high scores. The mathematical function that best explains this relationship is the mean or average value of the individual scores of the four habitat variables (U. S. Fish and Wildlife Service 1981).

Two methods can be used to calculate the mean or average value. The arithmetic mean is used when high scores fully compensate low scores. The geometric mean is used when high values only partially compensate the effect of low values (U. S. Fish and Wildlife Service 1981).

We use the geometric mean because elk appear to respond primarily to habitat variables of relatively low value, with secondary compensation provided by variables of higher value. During testing, the geometric mean appeared to best represent our expectations of the way elk might respond to a wide range of habitat conditions.

The equation for integrating habitat variables via the use of a geometric mean is described in the following section.

Habitat effectiveness for elk in western Oregon is calculated via the following equation:

$$HE_{SRCF} = (HE_S \times HE_R \times HE_C \times HE_F)^{1/N}$$

where: HE_{SRCF} = habitat effectiveness index considering the interaction of HE_S, HE_R, HE_C, and HE_F where:

HE_S = habitat effectiveness index derived from sizing and spacing of forage and cover areas,

HE_R = habitat effectiveness index derived from the density of roads open to vehicular traffic,

HE_C = habitat effectiveness index derived from the quality of cover,

HE_F = habitat effectiveness index derived from the quality of forage, and

$1/N$ = Nth root of the product taken to obtain the geometric mean where N = the number of habitat variables.

An example of this procedure is shown in the next section.

Evaluation Steps to Calculate Habitat Effectiveness

Previous sections introduced the four habitat variables of sizing and spacing of cover and forage areas, road density, cover quality, and forage quality, and identified a relationship between each and habitat use by elk. An equation to integrate the habitat variables to obtain one index of habitat effectiveness also was presented. In this section, the steps necessary to calculate habitat effectiveness are outlined.

The example that follows is for illustrative purposes only. We do not recommend the actual analysis be done by hand. Automated systems can analyze the data necessary to use our model (Eby and Bright 1986).

Step 1 – Select Analysis Area: The first step in evaluation of habitat for elk is selection of the analysis area. Boundaries of the analysis area must remain unchanged through time. Changes in boundaries during subsequent assessments invalidate the process and the data generated from it.

The size of the analysis area depends on the objectives of the evaluation. Assessment of one timber sale may require an area no larger than a third or fourth order drainage system in which the timber sale is located – probably about 1,000 to 6,000 acres in size. An area as large as a National Forest may be required to evaluate the cumulative effects of all timber sales within a ten-year management plan. In each case, the boundaries of the analysis area cannot change during subsequent assessments.

We suggest that the largest analysis areas be chosen on the basis of evaluation of cumulative effects within a specific management jurisdiction. Boundaries of a National Forest, State Forest, Bureau of Land Management District, or Management Unit of the Oregon Department of Fish and Wildlife are some examples to consider. Subunits of analysis within such jurisdictions could then be selected to evaluate individual timber sales or other actions specific to one drainage. We recommend that boundaries of a third or fourth order drainage be considered for this purpose. However, actions within each subunit ultimately must be evaluated in association with all other activities for the entire analysis area to monitor the cumulative effects on elk habitat. Failure to evaluate cumulative effects invalidates the entire assessment process.

Step 2 – Calculate HE_S: After the analysis area is selected, forage and cover areas must be identified on a base map (Figure 16). Witmer et al. (1985) defined forage areas and cover types for western Oregon (Figure 17). In our evaluation of sizing and spacing, no distinction between the cover types is made; all are simply identified as cover areas.

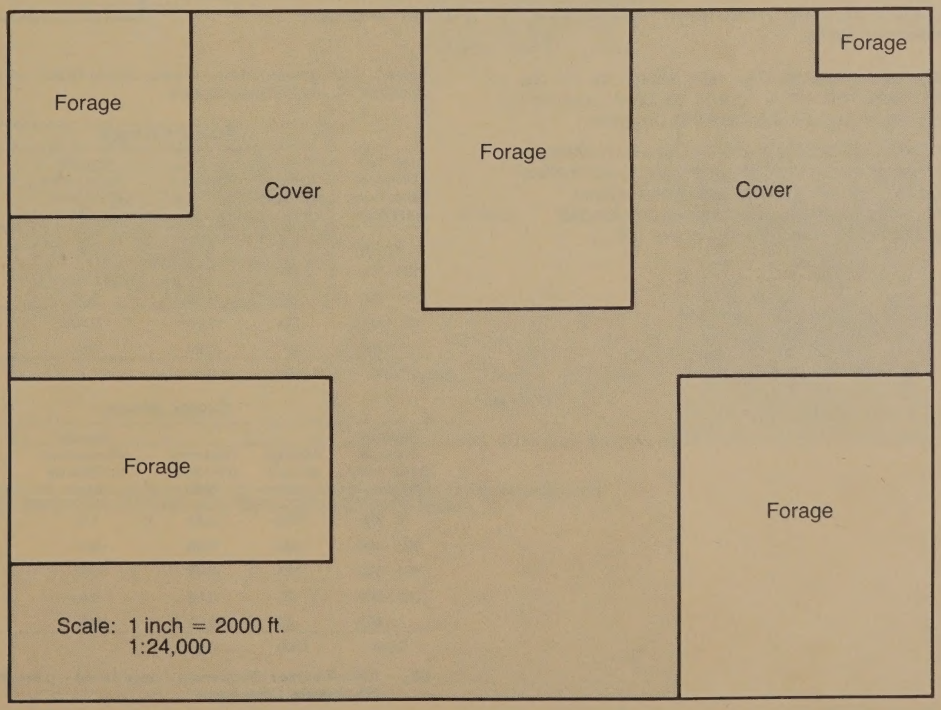

Figure 16. Identification of forage and cover in the analysis area.

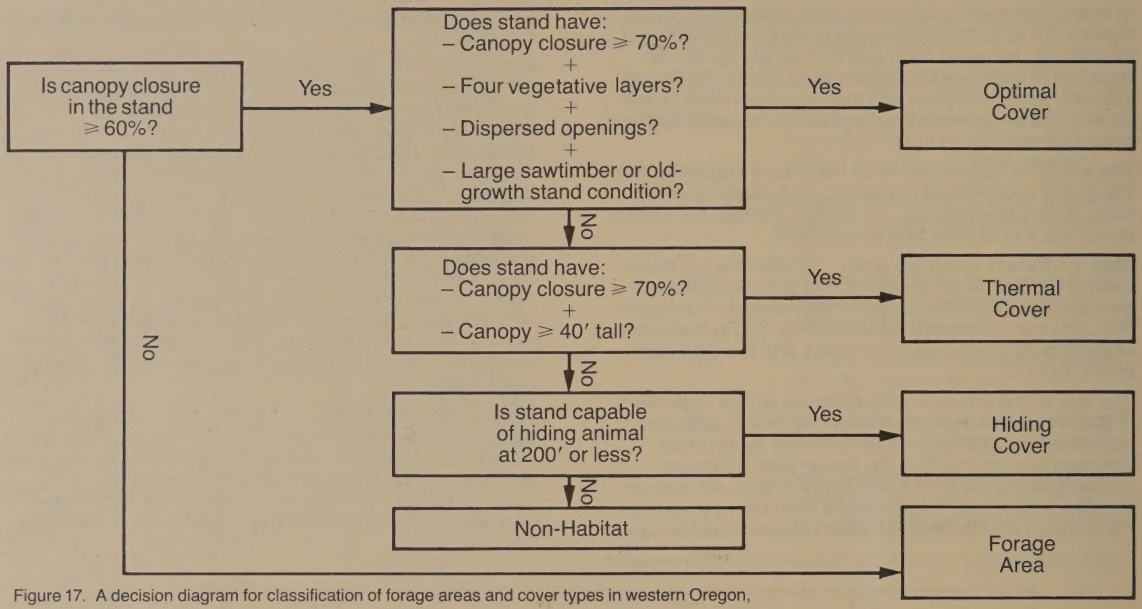

Figure 17. A decision diagram for classification of forage areas and cover types in western Oregon, based on Witmer et al. (1985).

Forage and cover areas are then delineated into the distance bands away from cover-forage edges described in Table 1. Figures 18 and 19 illustrate this process.

The proportion of the analysis area within each distance band is then weighted by the corresponding level of effectiveness (Table 3). The sum of all weighted values (Table 3) equals habitat effectiveness as influenced by sizing and spacing of forage and cover (HE_S).

Table 3. Data generated from Figures 18 and 19 that are used to calculate HE_S for the analysis area.

Forage Areas

100-Yard Distance Bands Away from Edge	Acreage of Forage Areas	Proportion of Analysis Area	X	[2]Habitat Effectiveness for Distance Band	=	Weighted Effectiveness for Distance Band
0–100	347	0.14	X	1.0	=	0.140
101–200	262	0.11		0.70		0.077
201–300	190	0.08		0.25		0.020
301–400	124	0.05		0.10		0.005
>400	47	0.02		0.05		0.001
SUM	970	0.4				0.243

Cover Areas

100-Yard Distance Bands Away from Edge	Acreage of Cover Areas	Proportion of Analysis Area	X	[2]Habitat Effectiveness for Distance Band	=	Weighted Effectiveness for Distance Band
0–300	1092	0.44	X	1.0	=	0.440
301–400	202	0.08		0.8		0.064
401–500	124	0.05		0.6		0.030
501–600	58	0.02		0.4		0.008
>600	33	0.01		0.2		0.002
SUM	1509	0.6				0.544

HE_S = 0.243 (Weighted Effectiveness, Forage Areas) + 0.544 (Weighted Effectiveness, Cover Areas)

= 0.79

[2]*From Table 1*

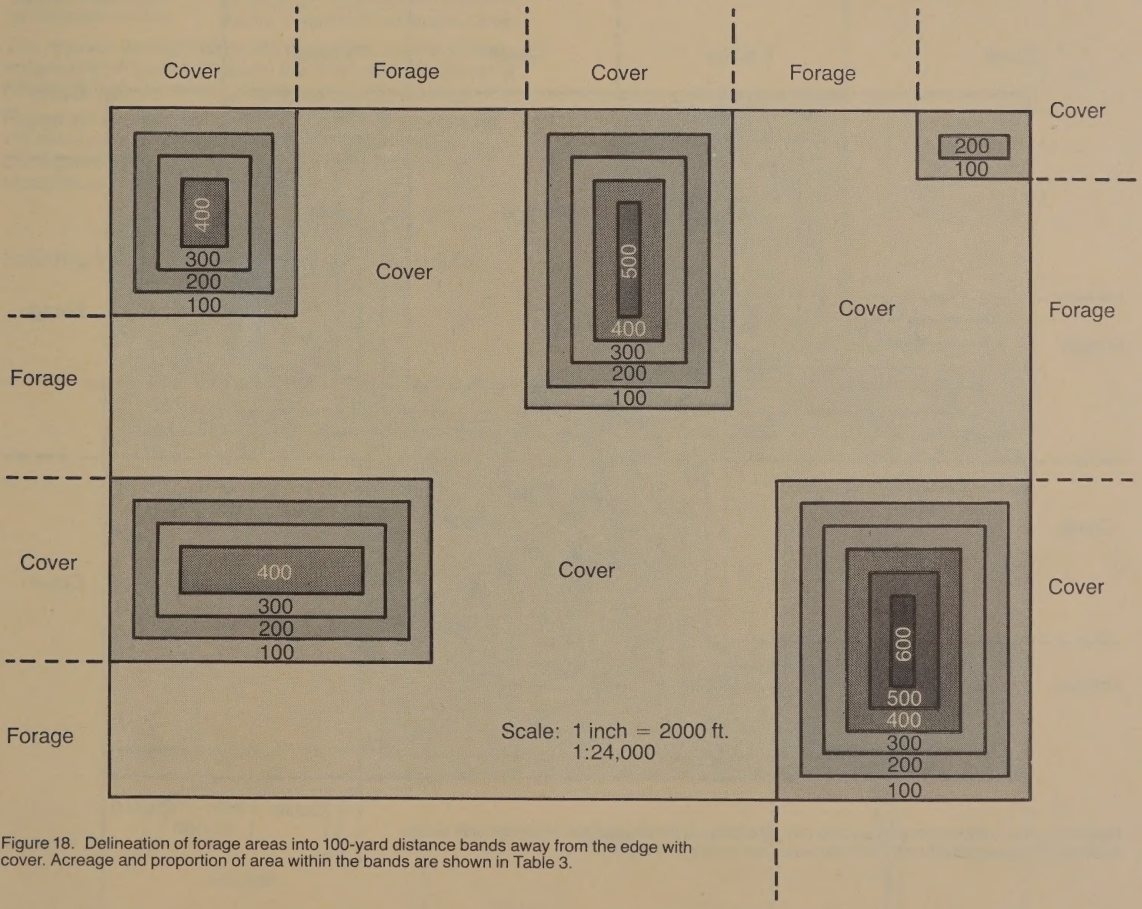

Figure 18. Delineation of forage areas into 100-yard distance bands away from the edge with cover. Acreage and proportion of area within the bands are shown in Table 3.

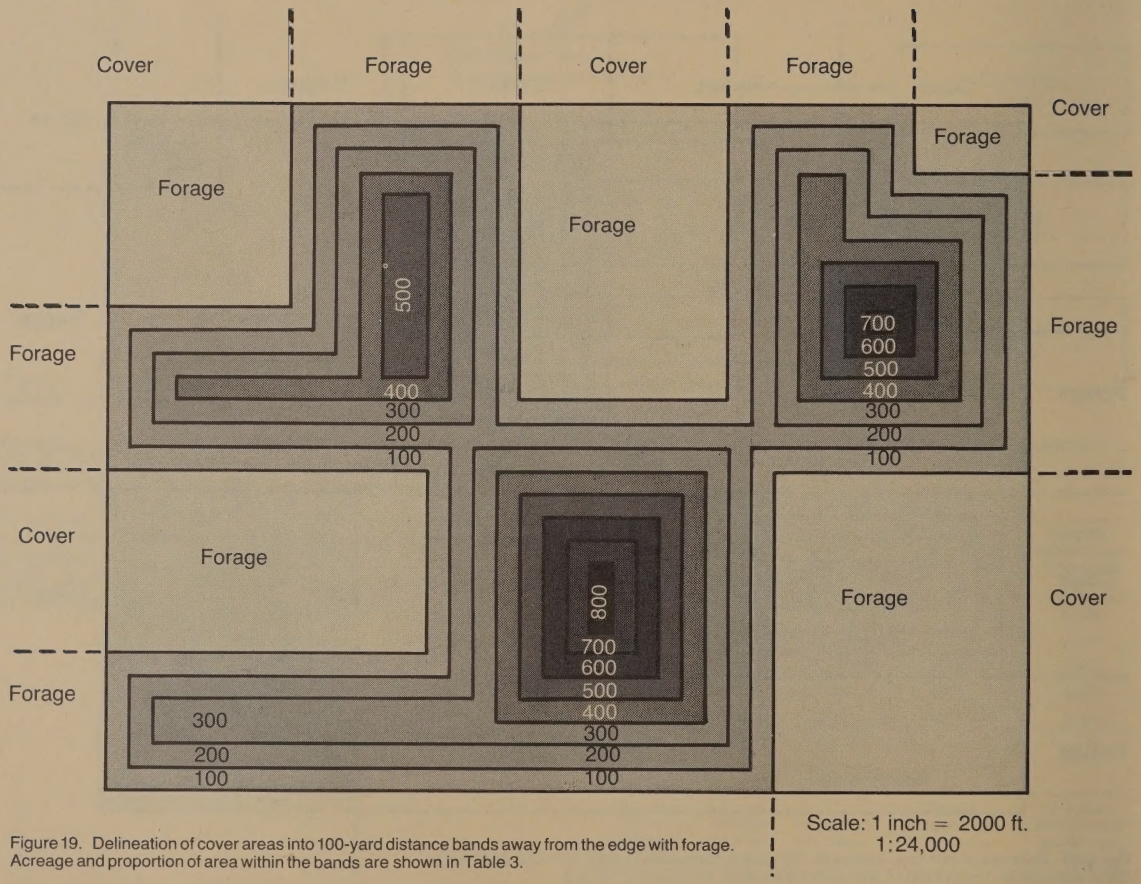

Figure 19. Delineation of cover areas into 100-yard distance bands away from the edge with forage. Acreage and proportion of area within the bands are shown in Table 3.

Step 3 – Calculate HE_R: To evaluate the effect of motorized traffic on habitat effectiveness for elk, all roads within the analysis area must be identified on a base map. The number of miles of roads open to motorized vehicles is then calculated.

The number of miles of roads open to motorized vehicles is then divided by the number of square miles present in the analysis area. This equals the density of roads open to motorized traffic. The equation is stated as:

$$\text{Density of roads open to motorized vehicles} = \frac{\text{Number of miles of roads open to vehicles}}{\text{Number of square miles in analysis area}}$$

The answer derived from the calculation above is then entered into Figure 8 to obtain the corresponding level of habitat effectiveness related to road density (HE_R).

Figure 20 illustrates this process. In the analysis area, 7.6 miles of roads are open to motorized vehicles. 3.9 square miles of habitat are present. Density of roads is calculated as follows:

$$\frac{7.6}{3.9} = \text{1.95 miles of roads open per square mile of habitat.}$$

Referring this density back to Figure 8, HE_R is 0.50.

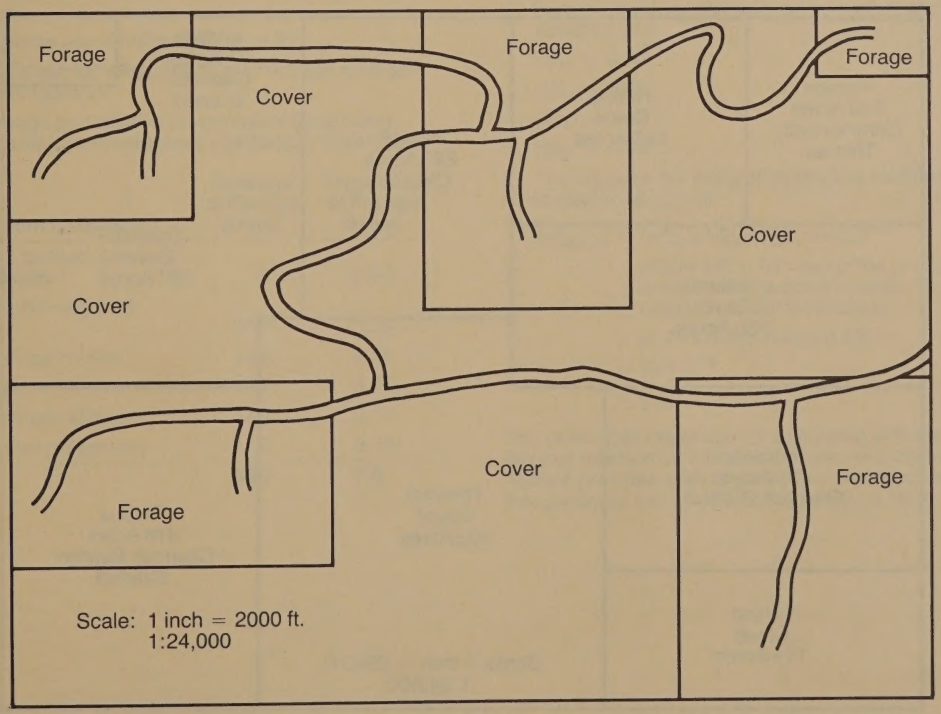

Figure 20. 7.6 miles of roads are open to motorized vehicles within the 3.9 square miles of the analysis area.

Step 4 – Calculate HE_C: To evaluate habitat effectiveness as influenced by the quality of cover, the steps outlined below are followed:

1. Identify optimal, thermal, and hiding cover types on a base map. Witmer et al. (1985) defined these cover types for western Oregon (Figure 17). If no cover areas are present in the analysis area, cover quality is rated at the 0.05 level of effectiveness.
2. If cover areas are present, calculate the proportion of area that each of the three cover types occupy relative to one another.
3. Weight the relative proportion of area occupied by each cover type (derived in No. 2) by each cover type's rating of habitat effectiveness – 1.0 for optimal cover, 0.5 for thermal cover, and 0.1 for hiding cover.
4. Sum the three products derived in No. 3.

Data from Figure 21 is used as an example of this process. Each step outlined below follows like-numbered instructions listed above:

1. Optimal, thermal, and hiding cover areas are identified in Figure 21.
2. The proportion of area that each cover type occupies relative to one another is: optimal – 0.43; thermal – 0.33; and hiding cover – 0.24.
3. Multiplying the proportion of area of each cover type by the respective rating of habitat effectiveness yields:

Cover Type	Proportion	X	Effectiveness	=	Product
Optimal	0.43		1.0	=	0.430
Thermal	0.33		0.5	=	0.165
Hiding	0.24		0.1	=	0.024
					0.62

4. Sum of the three products is:
   $0.430 + 0.165 + 0.024 = 0.62$
   $HE_C = 0.62$

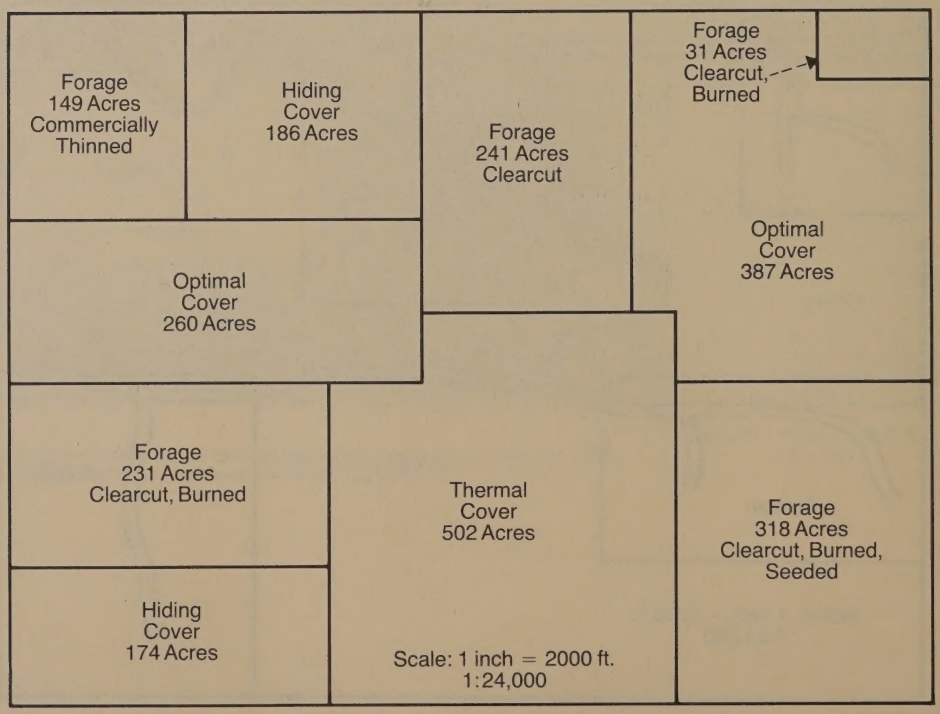

Figure 21. Identification of forage and cover types and their respective acreages in the analysis area.

Step 5 – Calculate HE_F:

1. Identify the forage areas on a base map; this was done previously during the calculation of HE_S. If no forage areas are present within the analysis area, forage quality is rated at the 0.05 level of effectiveness.
2. For each forage area present, select the category in Table 2 most appropriate to the land treatments that have been applied. Obtain information from landowner records or from general knowledge of land treatments commonly applied within the analysis area. Note that fertilization must be applied at least every three years to count as an effective treatment. All other treatments, once applied, are assumed to be effective over the life of the forage area.
3. Calculate the acreage of forage areas fitting within each treatment category. Sum the acreage; then calculate the relative proportion of area fitting within each category.
4. Weight the relative proportion of area fitting within each category by the corresponding level of habitat effectiveness from Table 2.
5. Sum the products derived in No. 4.

Data from Figure 21 is used as an example of this process. As done for the example of cover quality, each step outlined below follows like-numbered instructions listed above:

1. Forage areas are identified in Figure 21.
2. The land treatments applied to each forage area are shown in Figure 21.
3. The acreage and relative proportion of area fitting within the treatment categories identified in Table 2 are:

Treatment Category	Acreage of Forage Areas	Proportion of Forage Areas
1. Clearcut, burned, seeded, and fertilized	0	0.00
2. Clearcut, burned, and seeded	318	0.33
3. Clearcut and burned	262	0.27
4. Clearcut	241	0.25
5. Commercially thinned	149	0.15
6,7,8,9. Other categories	0	0.00
	970	1.0

4. Multiplying the proportion of area fitting within each treatment category by the corresponding level of habitat effectiveness from Table 2 yields:

Treatment Category	Proportion of Forage Areas	X	Effectiveness From Table 2	=	Product
1. Clearcut, burned, seeded, and fertilized	0.00	X	1.0	=	0.00
2. Clearcut, burned, and seeded	0.33		0.75		0.248
3. Clearcut and burned	0.27		0.50		0.135
4. Clearcut	0.25		0.25		0.063
5. Commercially thinned	0.15		0.10		0.015
					0.46

5. Sum of the products derived in No. 4 is:

$0.00 + 0.248 + 0.135 + 0.063 + 0.015 = 0.46$

$HE_F = 0.46$

Step 6 – Calculate HE_{SRCF}:

1. Habitat effectiveness derived from each of the four variables are:

$HE_S = 0.79$

$HE_R = 0.50$

$HE_C = 0.62$

$HE_F = 0.46$

2. The equation for integrating the four habitat variables to obtain HE_{SRCF} is:

$$HE_{SRCF} = (HE_S \times HE_R \times HE_C \times HE_F)^{1/N}$$

where 1/N = Nth root of the product taken to obtain the geometric mean. N = the number of habitat variables.

$$= (0.79 \times 0.50 \times 0.62 \times 0.46)^{1/4}$$

$$= (0.11)^{1/4}$$

$$= 0.58$$

The geometric mean can be calculated with the use of the root function on a hand calculator or small computer. Table 4 provides a list of geometric means computed for the quadratic root of $(HE_S \times HE_R \times HE_C \times HE_F)$.

Table 4. A list of geometric means computed for the quadratic root of $(HE_S \times HE_R \times HE_C \times HE_F)$.

$(HE_S \times HE_R \times HE_C \times HE_F)$	$(HE_S \times HE_R \times HE_C \times HE_F)^{1/4}$
1.0	1.0
0.9	0.97
0.8	0.95
0.7	0.91
0.6	0.88
0.5	0.84
0.4	0.80
0.3	0.74
0.2	0.67
0.18	0.65
0.16	0.63
0.14	0.61
0.12	0.59
0.10	0.56
0.08	0.53
0.06	0.49
0.04	0.45
0.02	0.38
0.018	0.37
0.016	0.36
0.014	0.34
0.012	0.33
0.010	0.32
0.008	0.30
0.006	0.28
0.004	0.25
0.002	0.21
0.0016	0.20
0.0012	0.19
0.0008	0.17
0.0004	0.14
0.0002	0.12
0.0001	0.10

Habitat Variables As Limiting Factors

Use of the geometric mean explains a species response to a number of habitat variables that interact and compensate one another in their effect on habitat use. However, under certain conditions elk use of habitat may be controlled by a single variable that overrides the influence of other habitat variables; this may occur when one or more variables approach minimal levels of effectiveness.

We applied this concept to our model while recognizing that additional field testing is necessary. We tested the model informally on a number of analysis areas that had extremely divergent habitat conditions, and developed Table 5 from the results. This table can be used by the forest manager to help interpret the results of an evaluation, and to aid decision-making.

Table 5. A guide to interpret results of habitat effectiveness scores.

Habitat Effectiveness Scores For Individual Variables (HE_X) or HE_{SRCF}	Habitat Condition
1.0	Optimal
0.9	Highly Viable
0.8	
0.7	
0.6	
0.5	Viable
0.4	
0.3	Marginal
0.2	
0.1	Possibly
0.05	Non-Viable

We assume that any of the four habitat variables may act as a "limiting factor" or "bottleneck" when habitat effectiveness for that variable drops below 0.20. In such cases, the probability of maintaining viable habitat for elk may be lowered significantly. For that reason, we recommend that managers view any HE scores below 0.20 with a "red flag" in need of immediate improvement.

One way to illustrate potential habitat deficiencies and the potential for improvement is shown in Figure 22. Under current management, habitat effectiveness as influenced by roads (HE_R) is extremely low, which in turn lowers overall effectiveness (HE_{SRCF}). However, with the implementation of a road closure plan, HE_R and thus HE_{SRCF} are increased substantially (Figure 22).

This type of exercise can be used to facilitate "brainstorming" sessions between biologists and managers. Improvements in each variable can be assessed in relation to the overall benefit each contributes toward improving the score of HE_{SCRF}. Managers can then structure forest practices for elk that yield the highest gain (or lowest decline) in HE_{SCRF} per unit of effort.

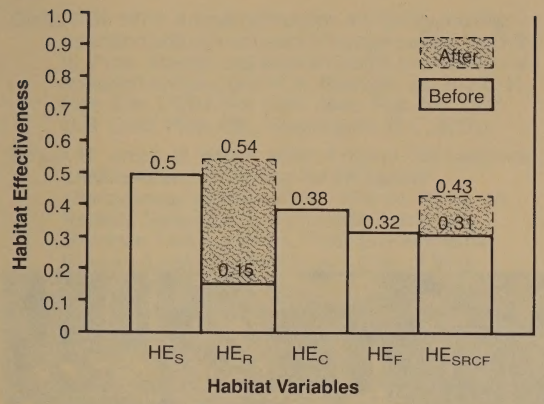

Figure 22. Comparison of habitat effectiveness scores before and after implementation of a proposed road closure plan.

Setting Objectives

The possibility that effectiveness of any habitat variable may decline to a potentially non-viable level underscores the importance of setting objectives. Objectives must be set for individual variables as well as for HE_{SRCF}. Objectives are needed to establish a common reference point to integrate elk management in land use plans, to implement those plans, and to monitor their relative success over time.

Habitat Effectiveness as a Measure of Change

Monitoring changes in habitat effectiveness is necessary to project impacts of land use proposals, to evaluate success of land use plans, and to establish trends in habitat condition. The percent change in habitat effectiveness from one point in time to another can be expressed using the following equation:

$$\text{Percent change in } HE_{SRCF} = \left(\frac{x-y}{x}\right)100$$

where: x = HE_{SRCF} at first point in time, and

y = HE_{SRCF} at second point in time.

Thus, if current HE_{SRCF} equals 0.80 and projected HE_{SRCF} equals 0.60, the percent change equals 25% as shown below:

$$\text{Percent change in } HE_{SRCF} = \left(\frac{0.8-0.6}{0.8}\right)100$$

$$= \left(\frac{0.2}{0.8}\right)100$$

$$= (0.25)100$$

$$= 25\%$$

We recommend this procedure be used to evaluate changes in HE_{SRCF} for all analysis areas. In the example above, an apparently small change in HE_{SRCF} of 0.2 (from 0.8 to 0.6) actually results in a 25% decline in habitat effectiveness. Similarly, the change in HE_{SRCF} shown in Figure 22 (from 0.31 to 0.43) results in a 39% increase in habitat effectiveness. This represents a significant change in the potential capability of habitat to produce elk. When this procedure is combined with the use of Table 5, the potential trade-offs between habitat management for elk and other forest uses are more clearly identified.

Management Tips

A myriad of forest practices can be used to improve habitat effectiveness scores. Thomas et al. (1979), Lyon et al. (1985) and Witmer et al. (1985) provide comprehensive guidelines and tips to consider when implementing beneficial practices or when attempting to reduce negative impacts.

We recommend these guidelines be reviewed before designing or implementing any habitat improvement projects. Without adequate planning, projects to enhance habitat or mitigate impacts will have a low probability of success.

Special Habitats

Our model evaluates elk habitat from a broad perspective. For that reason, specific habitats or areas used intensively by elk during certain seasons or for particular functions may not be fully recognized.

Riparian areas, remnant stands of old-growth, natural meadows, and pastures are some examples of potentially special habitats (Figure 23). These areas may be important to elk for such diverse activities as calving during spring, relief from heat stress during summer, rutting during fall, and shelter from severe storms during winter. Production of highly nutritious forage critical to successful reproduction by elk is another example.

Areas of special use must be identified from field work if they are to be managed effectively. Once identified, their importance to elk must be assessed in a site-specific manner.

Summary

Our model provides a systematic way to evalulate and monitor elk habitat; it is a planning tool that identifies impacts, provides options for mitigation, and allows managers to set objectives. It is not, however, a panacea for such functions, and must be considered a "first attempt" in the development of standard evaluation methods for elk habitat in western Oregon. As research continues, new evaluation methods will evolve to modify or substitute for earlier methods. Through time, this on-going process will improve knowledge and capability to manage elk and elk habitat.

Figure 23. Special areas or habitats important to elk during particular seasons or for specific functions must be identified during field work.

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